Technical Comparison of HD-DVD and Blu-Ray Technologies

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Abstract

Within the movie industry right now, there is a struggle to define the future of media delivery to homes. As HDTV (High Definition TeleVision) becomes more common place in America’s homes, the demand for a HD based media delivery system is quickly growing. The struggle for the industry to define a disc based method of high definition video delivery is galvanizing the companies involved into two separate camps. On one side of the debate is the group supporting the HD-DVD technology, which includes Toshiba, Microsoft, Paramount Home Entertainment, and Universal Pictures. On the other side of the debate is the group supporting the Blu-Ray Disc technology, which includes Sony, 20th Century Fox, Walt Disney, and Pioneer. On the surface, these two technologies are similar, but have significant differences. The goal of this paper will be to analyze these technical similarities and differences, as well as to determine how these factors will affect real world price and performance.

1. Introduction

The movie industry relies heavily on DVD sales to make a majority of their profits. In 2004, the movie industry made a record $15 billion dollars from DVD while the US box office only made $9.4 billion dollars [1]. These simple statistics show the vast importance of the DVD medium.

In 2004, HDTV sales made up 21% of all television sales. JupiterResearch, a division of Jupitermedia Corporation, has forecast that HDTV sales will constitute 70% of all television sales by the year 2010 [2]. This is indicative of the nature of US consumers: always wanting the next best thing.

There is also another fact about most US movie watchers that may not seem obvious: they prefer to watch their movies at home and not at the movie theater. Last summer, an Associated Press/AOL news poll found that 73% of adults were in this category [3].

Once you consider all of the facts mentioned above, it is plain to see that a disc based high definition delivery system will be a boon to Hollywood. When this medium arrives, it will revolutionize the industry, as well as increase the dependence of Hollywood on the purchase/rental industry in lieu of the box office. The industry realized this several years ago and began developing the successor to DVD. The problem of a format war quickly arose once two distinct formats were announced.

In February 2002, the specifications for the Blu-ray Disc (henceforth known as BD) were announced [4]. Shortly after this the Blu-ray Disc Association was founded and began recruiting companies to back the technology. Since then, the association has grown to over 140 companies, including Sony, 20th Century Fox, Walt Disney, Pioneer, Philips, and Samsung [5]. These companies have developed the technology into a streamlined product ready to replace DVD, but have been unable to fully garner acceptance due to the competition of another format: HD-DVD.

In November 2003, the DVD Forum placed its faith in the HD-DVD format [6]. Meant to be a true successor to the current DVD technology, HD-DVD is presented as being an easier changeover when compared to BD. Shortly after the DVD Forum announced its decision to back HD-DVD, the HD-DVD Promotion Group was formed. This association has since ballooned to over 120 companies. Some of the major companies involved in this effort are Toshiba, NEC, Memory-Tech, Sanyo, Microsoft, Paramount Home Entertainment, and Universal Pictures [7].

The involved companies on both sides exclaim that the technology they support is superior to the other, but that begs the question: which is truly the superior technology? This paper will answer that question by examining both which format is technically superior, as well as examining
which technology is more feasible from a production standpoint.

2. Blue Laser Optical Pickup

The one key technological advancement that enables both the BD and HD-DVD technologies to function is the blue laser optical pickup. With current DVD technology, information is read from the optical disc with a red laser, which operates at a wavelength of 650 nm. Both of these new technologies utilize a near violet laser that operates at 405 nm. In both technologies, the use of this much shorter wavelength results in the capability of resolving much smaller delineations. This corresponds to smaller tracks and pits on the disc, enabling both technologies to store large amounts of data on a disc the same physical size as a DVD. While both BD and HD-DVD implement this technology, they do so in different fashions. Because of this, the resolution they can attain is slightly different, causing the track widths and pit lengths for each technology to differ.

3. Blu-Ray Disc

This section will address the technical aspects of how the BD technology works, as well as what will be necessary for the manufacturing process. For simplicity reasons, we will only examine the 25 GB/layer version of the BD-ROM specification.

3.1. Technology

BD takes some radical steps away from the norm that DVD has established in an attempt to correct some specific problems. The first of these steps is utilization of a laser that operates at a wavelength of 405 nm. A second step is made by reducing the optical transmission and protection layer from .6 mm thick to a mere .1 mm. Another step is made by shortening the channel lengths for the pits and speeding up the disc rotation when compared to DVD. By utilizing all of these changes together, BD is able to make several other advancements that enable higher performance.

BD’s 405 nm laser is able to utilize a very tight .85 lens aperture. This is much tighter than DVD’s .6 lens aperture. This higher numerical aperture leads to double the density of the DVD laser. This density increase, along with the increase of 2.6 times density acquired from utilizing a laser with wavelength of 405 nm compared to 650 nm leads to a spot that is 1/5 of the size of a DVD laser’s spot. This leads to the logical conclusion that BD should be able to hold roughly 5 times the information of a DVD [9]. This calculation is confirmed by BD’s capacity of 25 GB for a single layer disc.

Due to this higher aperture, the necessity for a thinner cover layer was born. In any optical media system there is a certain amount of degradation received from disc tilt. This degradation is proportional to the thickness of the cover layer and the lens aperture cubed. By utilizing the extremely thin .1 mm cover layer with the high lens aperture, a radial tilt margin similar to that of a DVD is achieved.

![Figure 3.1-1 Necessity for a .1 mm Cover Layer](image)

With the much narrower laser beam of BD, it is able to utilize much shorter channel lengths that DVD. For instance, the data bit length is 111.75 nm for BD, as compared to DVD’s 267 nm data bit length. With this significant of a difference in channel length, it is only necessary for BD to spin roughly 2.11 times as fast as DVD to attain a date rate that is roughly 5.35 times that of DVD’s. This puts BD’s linear velocity at 7.367 m/s and its total data rate at 53.948 Mbit/s [9].

![Figure 3.1-2 SEM Photo of BD compared with DVD](image)
3.2. Manufacturing Process

While the technological changes BD introduces over DVD all serve to increase storage capacity and data rate, they also present some issues when it comes to manufacturing. Some of these issues will serve to make manufacturing simpler, while others will make it more difficult.

One very significant advantage of BD is its substrate. With DVDs, the laser has to read through a substrate that is .6 mm thick. If great care is not taken during the manufacturing of this substrate, problems of birefringence can be introduced. Since the data layer is located behind a very small .1 mm protective layer, problems with birefringence are avoided. Also, with BD the substrate is made in one piece; DVDs use two .6 mm substrates that must be glued together. Once you realize that the substrate is not read though with BD, you may conclude that a BD substrate can be made in one molding process and does not have to be transparent. With DVD substrates, they take two molding processes and must be uniform and optically transparent to avoid birefringence. The downside to this approach is the necessity for a hard cover layer to avoid damage.

To form a disc, the first step is the injection molding of the substrate. This is followed by cooling by the substrate is moved to the next unit. Here, the data layer is formed on the substrate by sputtering. After sputtering, the reflecting layer is covered by UV-curable resin using a spin coating technique. While the outer area of the resin is heated with IR, a different machine stamps out cover sheets from a roll. Next, the substrate with the resin is turned over and set on the cover sheet. UV radiation activates the resin and cures it. The manufacture of a dual layer disc is similar, with several added steps to the second layer and the space layer [9].

Perhaps the most important step of making any ROM disc media is the production of the master. With BD, there are three basic approached to this step, each representing a different level of investment necessary.

3.2.A. Phase Transition Metal Mastering

The first, called Phase Transition Metal (PTM) is the least expensive process to undertake. This process uses a type of inorganic photo-resist that, under heat and exposed to laser light, will change phase and become soluble in conventional developing fluid. The lens used in this process is a .95 numerical aperture device that is also used in conventional mastering processes. Since the material must be heated to react, the affected area is smaller than the laser spot. One advantage of this process is that it can be monitored in real time by observing changes in reflectivity. This is in contrast to conventional mastering where a complete master must be made, then tested. Using an optical pickup similar to those used in Blu-Ray recorders, this method is cheap, light, stable, and has low energy consumption [9].

![Figure 3.2.A.-1 – PTM Recording Mechanism [9]](image)

3.2.B. Deep-UV Liquid Immersion Mastering

Due to the size of the wiring spot necessary to master BD, conventional mastering equipment is unable to write the 25 GB ROM. This problem is solved with this process, enabling conventional mastering equipment to be upgraded to master BD. By injecting a small amount of liquid prior to the writing spot, then removing it after, the system can attain the necessary small spot. By utilizing existing infrastructure in this manner, transition costs are minimized [9].

![Figure 3.2-1 – BD Single Layer Process [9]](image)
3.2.C. Electron Beam Mastering

The final, most expensive solution for mastering is found in the electron beam mastering process. In this process, an electron beam recorder is used in lieu of a laser beam recorder so that higher density can be achieved. Downsides to this process include the extreme cost, as almost no existing mastering equipment can be reused, as well as slow record times. The upside to this process is its future applications. It has already been shown that it has the capability to record a 50 nm track pitch (compared to BD’s 320 nm track pitch), which shows the possibilities for 201 GB and higher ROMs [9].

![Figure 3.2.C-1 BD ROM compared to 201 GB ROM](image)

4. HD-DVD

This section will address the technical aspects of how the HD-DVD technology works, as well as what will be necessary for the manufacturing process.

4.1. Technology

Due to the fact that HD-DVD is intended to be more of a successor to DVD than a replacement, it shares many of the same qualities as DVD. One main departure is the use of the 405 nm laser pickup device. The numerical aperture of the pickup lens is only slightly more than DVD, so the disc must rotate at a faster speed to get the data rate higher. Utilizing these changes, HD-DVD makes enough of an improvement over the existing DVD to supply HD movie content to end-users.

As HD-DVD is meant to be an extension of the technology and concepts that conventional DVD is based up, it maintains the basic construction concepts of DVD. This consists of two transparent layers of .6 mm thick substrates with the data sandwiched between. These substrates must be optically transparent and capable of providing abrasion protection [10].

![Figure 4.1-1 – Comparison of DVD to HD-DVD](image)

**Figure 4.1-1 – Comparison of DVD to HD-DVD [10]**

Due to the .6 mm substrate, HD-DVD’s laser assembly utilizes a .65 lens aperture, which is just slightly higher than DVD’s .6 numerical aperture. By utilizing this slight increase in numerical aperture, increased error stemming from radial tilt is minimized. The increase in numerical aperture also leads to slightly increased laser density, when coupled with the density increase realized by the change from 650 nm to 405 nm, results in a density increase of about 2.9 times the 650 nm laser. This translates to a laser spot that is about 1/3 the size of the laser spot for DVD. This forces the conclusion that HD-DVD should have roughly 3 times the storage capacity of a conventional DVD, which is confirmed by HD-DVD’s capacity of 15 GB for a single layer disc.

The smaller beam of HD-DVD when compared to DVD allows for smaller pit lengths. In the case of the data pit, HD-DVD’s .204 nm pit length is significantly shorter than conventional DVD’s .267 nm length [11]. As this pit length is not very much smaller than DVD’s, the rotational speed must be significantly higher. This forces HD-DVD to operate at a linear velocity of 12.5 m/s, which is 3.58 times the operational speed of DVD [12]. Using the shorter pit lengths and the increased rotational speed, HD-DVD attains a total data rate of 36.55 Mbits/sec.

4.2. Manufacturing Process

Great care was taken with the specifications of HD-DVD to ensure that the transition from DVD to HD-DVD would be as easy as possible for manufactures. While some changes are necessary to allow for the smaller pits and smaller track pitches of HD-DVD, these changes are mostly on the mastering side of the process.

Conventional DVD’s two piece substrate process is continued with HD-DVD. In this process, two separate substrate pieces are molded, each .6 mm thick, then glued together with the data in the middle. Great care must be taken during the molding process to maintain constant heat to the plastic. If this crucial step is not taken, the
edges of the plastic can cure into hardened plastic before the middle, which can lead to serious birefringence problems. A key advantage of the thick substrate method is the natural protection that it provides to the data.

![Figure 4.2-1 – Injection Molding Process](image)

To actually manufacture a HD-DVD, the process is almost identical to that of a DVD, except with tighter tolerances on most parameters. The first step is to injection mold the two substrates. Once these substrates are molded and cured, the reflective layer is sputtered onto them. After this step, each substrate is coated with an IR-curable resin, squeezed together, and then cured under an infrared light. The manufacturing of a dual layer disc is very similar, with some added steps to accommodate a space layer and the second data layer [13].

As with all optical mediums, one of the most important steps of the process is the manufacture of the master copy. As with most of the manufacturing process of HD-DVD, this step is not significantly different than conventional DVD. One common process utilizes a 257 nm laser with a photoresist and glass substrate [14]. This process is analogous to the process that conventional DVDs use, requiring very little investment to bring current producing capabilities up to HD-DVD standards.

5. **Comparison**

Now that there is a clear understanding of the technologies underlying BD and HD-DVD, we will perform a comparison of the two technologies and their manufacturing processes.

5.1. **Technology**

The first of many technological differences between BD and HD-DVD is the substrate. HD-DVD continues to use the tried and true dual .6 mm substrate method that DVD has used for years, while BD steps aside and devises a new way, using its 1.1 mm thick substrate. This gives BD a clear advantage as the data is placed much closer to the surface, causing the laser to only have to read through a .1 mm thick cover layer as opposed to HD-DVD’s .6 mm thick substrate. BD’s approach also has advantages in that the substrate no longer needs to be optically consistent and transparent, as the laser does not read through it. This could lead to less expensive plastics being used for this substrate.

A second key difference is in the numerical aperture of the lens assembly. Due to HD-DVD’s dependence on the .6 mm thick substrate, the numerical aperture is only able to be .65, which is only .05 higher than that of DVD’s. With BD’s .1 mm thick cover layer, it is able to use a much tighter numerical aperture of .85, which is .25 higher than DVD’s.

The difference in numerical aperture allows BD to focus its laser’s energy into a much denser, smaller spot than HD-DVD. This allows BD to utilize shorter channel lengths and lower speeds than HD-DVD, while still eclipsing its performance. BD’s data rate is specified at 53.948 Mbit/s, while HD-DVD’s data rate is calculated to be 36.55 Mbit/s. These changes also allow BD to have a total storage of 25 GB for a single layer disc, while HD-DVD only has 15 GB.

5.2 **Manufacturing Process**

One key difference between BD and HD-DVD when it comes to manufacturing is the substrate. With BD, there is only one cycle necessary, as there is only one substrate. With HD-DVD, two cycles are necessary, due to the two substrates. Also, with BD, the substrate does not have to be optically uniform and transparent, while it does with HD-DVD. One problem that the BD substrate presents is the necessity for a hard cover layer. This problem is not present in HD-DVD due to the thick substrates.

The other key difference is in the production of the master copy. With BD, there are significant changes necessary to make the changeover from DVD. The BD Association has come up with three basic ways to make the master discs because of this, but all of them require significant changes to be made to the existing process that DVD uses. Any of these changes that would be necessary for BD are extremely significant when compared to the changes that would be involved in the changeover to HD-DVD. Because HD-DVD was engineered to be a successor to DVD, the mechanical changeover necessary is very minimal.
6. Conclusion

As far as the technology is concerned, BD is clearly superior to HD-DVD. BD takes many of the problems that DVD has and fixes them in an effort to make a better, higher capacity, faster medium. HD-DVD basically changes from a 650 nm laser to a 405 nm laser and tweaks conventional DVD’s technology and concepts.

If you compare the two technologies based on which one would be easier to implement from a manufacturing standpoint, HD-DVD is clearly untouchable. HD-DVD would require very little work on manufacturing lines to begin production. BD, no matter which mastering process is utilized, will require significant work to begin production.

7. References


